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## UTILITY PATENT APPLICATION TRANSMITTAL

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Assistant Commissioner for Patents  
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Washington, DC 20231

Dated: June 7, 2000

Sir:

Transmitted herewith for filing is the utility patent application of:

Inventors: Anko BÖRNER

For: Calibration System For Calibrating Orientation Parameters Of Digital  
Optoelectronic Sensors In A Mobile Carrier Used For Remote Reconnaissance

Enclosed are:

- Transmittal letter (2x) with Fee Computation Sheet
- General Authorization For Payment of Fees (2x)
- Title Page, Specification, Claims 1 to 6 & Abstract (13 pages [total number of pages of application])
- Unexecuted Declaration and Power of Attorney (2 p.)
- 1 sheet of drawings (Figs. 1 )
- Check for \$690 for filing fee
- Information Disclosure Statement
- PTO Form 1449 with copies (3 docs.) of cited references
- Return Receipt Postcard

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☒ The Commissioner is hereby authorized to charge payment of the following fees associated with this application or credit any overpayment to Deposit Acct. No. 03-2412.

☒ Any additional filing fees required under 37 CFR 1.16.

☒ Any patent application processing fees under 37 CFR 1.17

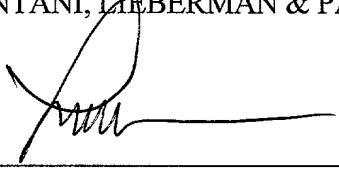
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- ☒ The issue fee set in 37 CFR 1.18 at 3 months from mailing of the Notice of Allowance, pursuant to 37 CFR 1.311 (b) provided the fee has not already been paid by check.
- ☒ Any filing fees under 37 CFR 1.16 for presentation of extra claims.

☒ Priority is claimed for this invention and application, corresponding applications having been filed in **Germany** on **June 07, 1999**, No. **199 27 012.0**.

Respectfully submitted,  
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**THE UNIVERSITY OF CHICAGO**

# CALIBRATION SYSTEM FOR CALIBRATING ORIENTATION PARAMETERS OF DIGITAL OPTOELECTRONIC SENSORS IN A MOBILE CARRIER USED FOR REMOTE RECONNAISSANCE

**Anko BÖRNER**

## **BACKGROUND OF THE INVENTION**

### **1. Field of the Invention**

The invention relates to a calibration device for calibrating the orientation parameters of digital optoelectronic sensors arranged in a carrier such as a aircraft or a satellite for remote reconnaissance such as photogrammetry.

### **2. Description of the Related Art**

Digital sensors are already playing a significant role in remote sensing today due to their characteristic of recording data in digital form and then transmitting the data to a receiving station. Due to the developments in the field of semiconductor electronics, digital sensor systems will also be capable of advancing within a foreseeable time into the field of traditional photogrammetry and replacing the analog pick-up systems such as, for example, aerial cameras which are based on film.

For the evaluation of the sensor data especially in the case of photogrammetric tasks, considerable importance attaches to the knowledge about the attitude and the position, i.e., orientation parameters, of the pick-up system. It is only if these orientation parameters are known that geometric statements can be made about the observed objects. The accuracy of these so-called orientation parameters determines the quality of the measured geometric variables. In this context, the outer orientation parameters specify the attitude and position of the center of projection of the pick-up system and the inner orientation parameters describe the relationship between the center of projection and the image plane.

The orientation parameters for analog aerial photos are generally determined with the aid of register points, i.e., points on the ground having known locations, during image analysis. The coordinates of these register points are surveyed accurately. The determination of the orientation parameters has been supported in recent years by using GPS and navigation systems.

This traditional approach presents special problems in the determination of the orientation parameters for image data which have been picked up by line scanners. Due to the fact that a rigid image geometry is lacking, the orientation parameters must be redetermined each time an image line is picked up by a line scanner.

A prior art parameter determination method is disclosed, for example, in German reference DE 38 02 219 A1 wherein a series of overlapping individual pictures is made at regular time intervals by an optoelectronic planar pick-up camera allocated to one or more line scanners or a combination of such cameras. The positions of corresponding picture elements or picture zones in the overlapping area of adjacent single planar pictures are in each case selected for the mutual orientation of the pick-up positions of the planar camera. The orientation data of the optoelectronic planar camera is transmitted by permanent alignment or measurement of the relative alignment to the line scanner supported by a time correlation between both data streams. To carry out the method, planar detectors are preferably arranged in the same focal plane between the line scanners.

As the orientation parameters obtained by conventional methods of the photogrammetry always refer to the center of projection, some problems occur during the

measuring of these variables. If the position is determined by GPS, the position of the GPS antenna is determined, as a rule. The three angles of rotation are also not measured with respect to the center of projection of the sensor. Moreover, gyroscopic systems only register changes in the angle of velocity, as a rule. To determine an absolute angle, reference angles are necessary at least at one point in time. All six parameters of the outer orientation parameters are thus subject to an offset. These variables are not known and must be determined by additional measurements such as, for example, by theodolites or by evaluating register points. This results in additional expenditure for measurement technology and in additional error sources. Furthermore, this method prevents complete on-board processing.

An arrangement for obtaining highly accurate data from the air is disclosed in German reference DE 43 14 742 A1 which comprises a sensor system having at least non-imaging sensors for determining anomalies of the conductivity and/or disturbances in the earth magnetic field in the area or, respectively, ground to be probed, and a flight guidance system which operates in conjunction with a differential position determining system, the sensor and flight guidance system being arranged in a helicopter. The differential position determining system includes a GPS reference station arranged at a fixed location with known coordinates in the vicinity of the area to be probed. The GPS reference station operates in conjunction with a DGPS transmitter for transmitting position correction data to a DGPS receiver in the helicopter.

A surveying instrument is disclosed in German reference DE 26 38 621. The surveying instrument includes a device for measuring angles such as a theodolite in which the

values measured by this device such as the elevation angle or horizontal direction are dependent on leveling errors during the installation. Accordingly, a device for determining leveling errors of the equipment may be permanently connected to the equipment, wherein a computing unit which calculates from the measurement value and leveling error the value of the corrected measured variable, the leveling error being determined by the output signal of a Schottky barrier diode which is mounted rigidly on the equipment and to which a light ray reflected from a liquid surface is applied.

### **SUMMARY OF THE INVENTION**

The invention is therefore based on the technical problem of creating a calibration system for calibrating the orientation parameters of digital optoelectronic sensor systems in mobile carriers (e.g. aircraft or satellites) for remote reconnaissance such as photogrammetry, which enables the offset of the orientation parameters to be determined and processed further on board.

A calibration system for calibrating orientation parameters of a digital optoelectronic sensor system according to an embodiment of the present invention includes an attitude and position determining system arranged in a mobile carrier, such as an airplane or a satellite, for determining orientation parameters during flight. The calibration further includes an optoelectronic component that emits light in a defined direction with respect to the attitude and position determining system arranged in the mobile carrier. A planar optical detector is arranged relative to the optoelectronic device for detecting the reflection of radiation emitted from the optoelectronic device and reflected off of a reference module arranged on the ground. The orientation parameters of the reference module are known. Therefore, the offsets of the orientation parameters of the attitude and position determining system may be determined by evaluating the radiation emitted by the light-emitting component, reflected from the reference module and received by the planar detector. The calibration system comprises at least one attitude and position determining system, at least one light-emitting optoelectronic component, a planar optical detector and a reference module which is arranged on the ground and the orientation parameters of which are known. The radiation transmitted by the light-emitting



component is reflected from the reference module and detected by the planar detector. Calculated orientation parameters are computed using the values detected by the planar detector and the known parameters of the reference module. The offset of the orientation parameters determined by the attitude and position determining system are then detected by comparison of the orientation parameters determined by the attitude and position determining system to the calculated orientation parameter values.

In a preferred embodiment, the optoelectronic sensor system is constructed as a charge-coupled device (CCD) line scanner in which planar optical detectors constructed as CCD matrices are arranged between the CCD lines in the same focal plane. As a result of the arrangement, the calibration is evaluated by the evaluation electronics proper of the optoelectronic sensor system which considerably simplifies the configuration.

The various features of novelty which characterize the invention are pointed out with particularity in the claims annexed to and forming a part of the disclosure. For a better understanding of the invention, its operating advantages, and specific objects attained by its use, reference should be had to the drawing and descriptive matter in which there are illustrated and described preferred embodiments of the invention.

**BRIEF DESCRIPTION OF THE DRAWINGS**

In the drawing, Fig. 1 is a schematic view of an optoelectronic sensor system with an integrated calibration device according to an embodiment of the present invention.

**DETAILED DESCRIPTION OF THE PRESENTLY PREFERRED EMBODIMENTS**

An optoelectronic sensor system 1 comprises an attitude and position determining system 10 and input optics 2 and three charge-coupled device (CCD) lines 3 which are arranged in parallel with one another in a focal plane 4. The attitude and position determining system 10 facilitates determining the exact location of reconnaissance or survey data scanned via the input optics 2 and CCD lines 3. The calibration device comprises two or more laser diodes 5, two or more CCD matrices 6 and a reference module 7 comprising a number of submodules 8. The orientation, i.e., attitude and position, of each submodule 8 of the reference module 7 is known with high accuracy. The CCD matrices 6 of the calibration device are arranged between the CCD lines 3 in the focal plane 4. The laser diodes 5 are arranged between the focal plane 4 and the input optics 2 so that they do not interfere with the visual range of the CCD lines 3. The entire calibration device is integrated into the optoelectronic sensor system 1 with the exception of the reference module 7 which is arranged on the ground. The beams of rays from the laser diodes 5 are widened by lenses (not shown), emerge through the input optics 2 and impinge on the reference module 7. The beams of rays are reflected from the reference module 7 and projected on the input optics 2 from where they are imaged onto the focal plane 4 and the CCD matrices 6 arranged thereon. The relative attitude and position of the focal plane 4 with respect to the known orientation of the reference module 7 is then determined from the signal of all CCD matrices 6 in the circuitry of the attitude and position determining system 10. Using the measured attitude and position data, the offset of the attitude and position determining system 10 may then be determined for all six

orientation parameters, thus providing an absolute tie-up of the measured variables for the six orientation parameters. The evaluation unit that is required for evaluating data for the CCD lines 3 may also be used for evaluating the data received by the CCD matrices 6 so that the hardware expenditure for incorporating the inventive calibration system into an existing optoelectronic sensor system 1 is essentially restricted to adding the CCD matrices 6 and the laser diodes 5 to the existing system.

If the optoelectronic sensor system 1 is used, for example, for purposes of photogrammetry in an aircraft, the reference module 7 may be set in concrete at a particular position, for example at an airport, so that the reference module 7 is located in an unchangeable defined position and attitude. As a result, the optoelectronic sensor system 1 may be recalibrated before each flight.

The invention is not limited by the embodiments described above which are presented as examples only but can be modified in various ways within the scope of protection defined by the appended patent claims.

**CLAIMS**

I claim:

1           1. A calibration system for calibrating orientation parameters of a digital  
2   optoelectronic sensor system arranged in a mobile carrier for remote reconnaissance, said  
3   calibration system comprising:  
4           an attitude and position determining system for determining orientation  
5   parameters of the optoelectronic sensor system;  
6           an optoelectronic component emitting radiation in a defined direction with  
7   respect to said attitude and position determining system;  
8           a reference module arranged in a known fixed location; and  
9           a planar optical detector arranged relative to said optoelectronic component for  
10   receiving a reflection of the radiation emitted by said optoelectronic component and reflected  
11   from said reference module, said planar optical detector being operatively connected to said  
12   attitude and position determining system so that offsets in the orientation parameters  
13   determined by said attitude and position determining system are detected by comparison of the  
14   orientation parameters determined by said attitude and position determining system to  
15   calculated orientation parameters computed using the reflection of the radiation received by  
16   said planar optical detector and the known fixed location of said reference module.

1           2. The calibration device of claim 1, wherein said optoelectronic component  
2   comprises a laser diode.

1                   3.     The calibration system of claim 1, wherein said planar optical detector  
2 comprises a CCD matrix.

1                   4.     The calibration system of claim 1, further comprising a CCD line  
2 scanner comprising CCD lines arranged on a focal plane of device optics for obtaining remote  
3 reconnaissance data, wherein said planar optical detector is arranged between said CCD lines.

1                   5.     The calibration device of claim 4, wherein said optoelectronic  
2 components are arranged between said focal plane and said device optics such that they are  
3 located outside a beam path of useful radiation of said CCD lines.

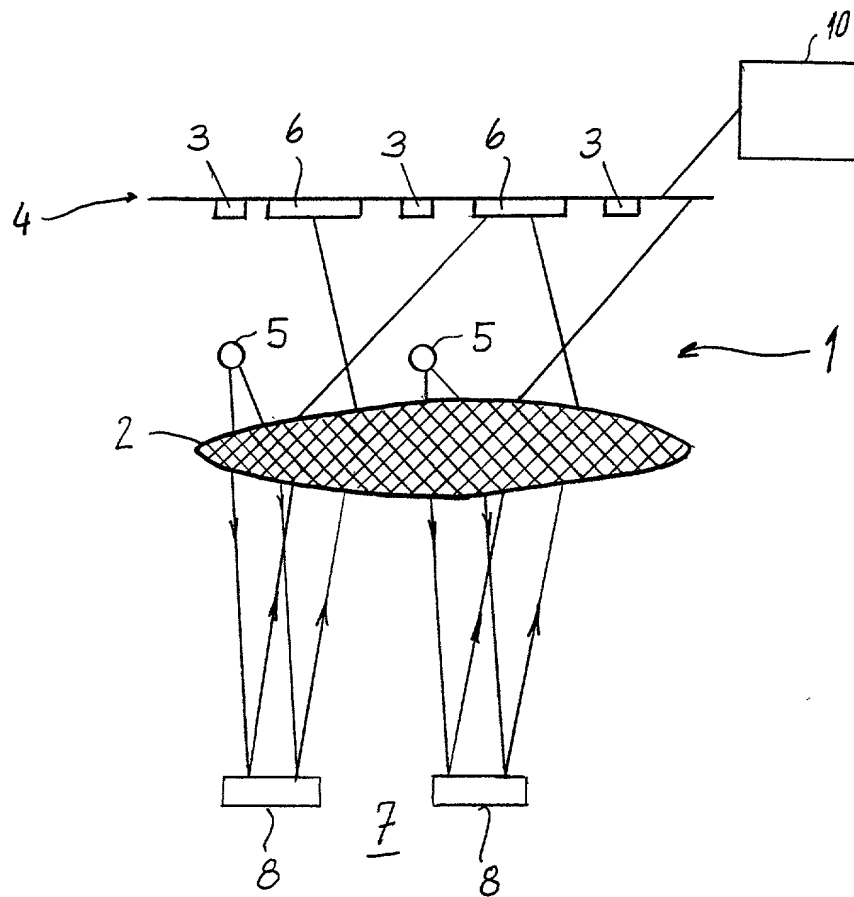
1                   6.     The calibration device of claim 1, wherein said reference module  
2 comprises a mirror set in concrete.

**ABSTRACT OF THE DISCLOSURE**

A calibration system for calibrating orientation parameters of a digital optoelectronic sensor system includes an attitude and position determining system arranged in a mobile carrier, such as an airplane or a satellite, for determining the orientation parameters in flight. An optoelectronic component emits light in a defined direction with respect to the mobile carrier. A planar optical detector is arranged relative to the optoelectronic device for detecting the reflection of radiation emitted from the optoelectronic device and reflected off of a reference module arranged on the ground. The orientation parameters of the reference module are known, wherein the offsets of the orientation parameters of the attitude and position determining system may be determined by evaluating the radiation emitted by the light-emitting component, reflected from the reference module and received by the planar detector.

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Fig. 1



004090-4688560



## **DECLARATION AND POWER OF ATTORNEY FOR PATENT APPLICATION**

As a below named inventor, I hereby declare that:

My residence, post office address and citizenship are as stated below next to my name.

I believe I am the original, first and sole inventor (if only one name is listed below) or an original, first and joint inventor (if plural names are listed below) of the subject matter which is claimed and for which a patent is sought on the invention entitled

### **CALIBRATION SYSTEM FOR CALIBRATING THE ORIENTATION PARAMETERS OF DIGITAL OPTOELECTRONIC SENSORS IN A MOBILE CARRIER USED FOR REMOTE RECONNAISSANCE**

the specification of which is attached hereto.

I hereby state that I have reviewed and understand the contents of the above-identified specification, including the claims, as amended by any amendment referred to above.

I acknowledge the duty to disclose information which is material to the patentability of this application in accordance with Title 37, Code of Federal Regulations, Section 1.56(a).

I also acknowledge the duty to disclose information which is material to the patentability of this application in accordance with Title 37 CFR 1.63(d), which occurred between the filing date of the prior application and the filing date of the continuation-in-part application, if this is a continuation-in-part application.

I hereby claim foreign priority benefits under Title 35, United States Code, Section 119 of any foreign application(s) for patent or inventor's certificate listed below and have also identified below any foreign application for patent or inventor's certificate having a filing date before that of the application on which priority is claimed:

<b>Prior Foreign Application:</b>	<b>Country:</b>	<b>Germany</b>
	<b>Appln. No.:</b>	<b>199 27 012.0</b>
	<b>Filed:</b>	<b>June 07, 1999</b>

I hereby appoint the following attorneys and/or agents to prosecute this application and to transact all business in the Patent and Trademark Office connected therewith:

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I hereby declare that all statements made herein of my own knowledge are true and that all statements made on information and belief are believed to be true; and further that these statements were made with the knowledge that willful false statements and the like so made are punishable by fine or imprisonment, or both, under Section 1001 of Title 18 of the United States Code and that such willful false statements may jeopardize the validity of the application or any patent issued thereon.

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